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(54) **Information recording device.**

(57) A device is described for recording information which is applied at a bit frequency which is lower than that at which it is recorded. The difference in bit frequency is compensated by an input buffer memory (6). Recording is interrupted each time until sufficient information is present in the input buffer memory (6) so as to record a subsequent packet of information. During the recording interruptions the recorded information pattern is read. To obtain an indication signal Vinc indicating the recording quality, the read signal VI is analyzed by means of an analysis circuit (11). The indication signal is used to adapt the setting of the write parameters. Based on this indication signal, a re-recording operation can be initiated.

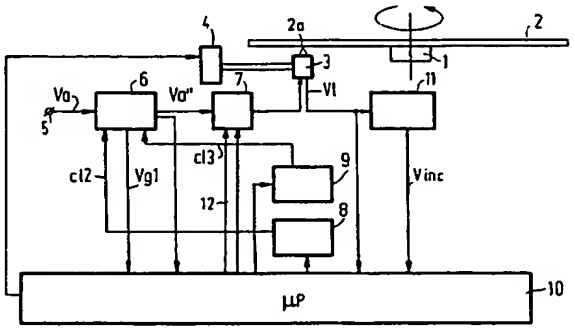


FIG.1

EP 0 559 277 A1

The invention relates to a device for recording information on a record carrier, which device comprises a read/write head of a type which can be brought to a read and a write state and is adapted to provide, in the write state in response to a write signal, a corresponding information pattern in a portion of the record carrier which is scanned by a scanning point fixed by the position of the read/write head, and which is adapted to provide, in the read state, a read signal which is indicative of the information pattern in the portion of the record carrier scanned by the scanning point, a driving device for causing the scanning point to scan the record carrier in accordance with a track-shaped path, an input buffer memory for storing information to be recorded at a given load rate, a retrieval circuit for retrieving a packet of information from the input buffer memory at a retrieval rate which is higher than the load rate, a write circuit for converting the packet of retrieved information into write signals for the read/write head, control means for interrupting the recording operation after the information pattern corresponding to said packet has been recorded, for a repeated scanning of the information pattern corresponding to the last retrieved packet and for retrieving a subsequent packet of information from the input buffer memory and starting the recording of an information pattern corresponding to said subsequent packet in a portion of the record carrier adjoining the last recorded information pattern, such that a filling level of the input buffer memory remains between given limits.

A device of this type is known from EP-A 0,429,139 (PHN 13.146). A requirement for recording information is that the recording should have such a satisfactory quality that it enables reliable reading. Due to parameter variations or incidental disturbances of the write process, a portion of the recorded information may only be partly readable.

It is an object of the invention to provide means with which the recording quality can be monitored during recording.

For a device as described in the opening paragraph this object is achieved in that the device comprises means for deriving an indication signal which is indicative of the quality of the recorded information pattern on the basis of the read signal which is supplied by the read/write head during the repeated scanning operation.

In the device according to the invention advantageous use is made of the fact that due to the periodical interruption of the recording operation extra time will become available for monitoring the recording quality on the basis of the read signal. The indication signal can be used to improve the recording quality.

In accordance with a further embodiment of the invention such an improvement can be obtained by means of a device which is characterized in that it comprises means for adapting, in dependence upon the indication signal, the write parameter which influences a relation between the information to be recorded and the information pattern provided and corresponding to said information.

An embodiment of the recording device in which the indication signal is determined on the basis of the number of errors in the information which has been read is characterized in that the device comprises a read circuit for regaining the recorded information from the read signal, in which the means for supplying the indication signal are provided with error detection means for detecting errors in the regained information and with means for counting errors in the read information in accordance with a given counting criterion, the means for deriving the indication signal being adapted to supply an indication signal which is indicative of the number of counted errors.

A further embodiment of the recording device is characterized in that the device comprises means for detecting whether the indication signal satisfies a predetermined criterion, storage means for storing the information associated with the last recorded information pattern, the control means being adapted to repeat the recording of at least those portions of the information stored in the storage means for which the indication signal does not satisfy said criterion.

Due to the repeated recording, the recording quality is also improved.

A further embodiment of the recording device is characterized in that the device comprises means for adding error-correcting codes to the information to be recorded, the means for detecting errors being adapted to detect errors which are not corrigible by means of the error-correcting codes, the indication signal indicating the number of incorrigible errors.

This embodiment has the advantage that a very reliable recording is obtained with a very small number of incorrigible errors in the information which has been read.

Further embodiments of the recording device and their advantages will hereinafter be described with reference to Figs. 1 to 6 in which

Figs. 1 and 6 show different embodiments of the recording device according to the invention,

Figs. 2, 4 and 5 show flow charts of programs performed by program-controlled control units of the recording device and,

Fig. 3 is a plan view of a record carrier in which information has been recorded by a recording device according to the invention.

Fig. 1 shows a first embodiment of a device according to the invention for recording information in a recording layer of a record carrier. The device

comprises a motor 1 for causing a disc-shaped record carrier 2 of an inscribable type, for example an optical record carrier, to rotate about its axis, which record carrier has a spiral track intended for recording information. A read/write head 3 scanning the record carrier in accordance with a path described by a scanning point 2a fixed by the position of the read/write head 3 is arranged opposite the rotating record carrier 2. The read/write head 3 may be, for example a conventional optical read and write head with which the record carrier 2 can be scanned by means of a radiation beam. The system has a tracking system (not shown) of a conventional type which ensures that the scanning point 2a substantially coincides with the centre of the track. The device is further provided with a focus control (not shown) for keeping the scanning beam focused on the record carrier, a scanning rate control system (not shown) of a conventional type for controlling the rate at which the record carrier 2 is moved along the read/write head 3. The read/write head 3 may be radially displaced with respect to the record carrier 2 by means of a radial displacement system 4.

For given applications such as, for example, in the system described in EP-A-0,429,139 or for the Mini-Disc system the bit frequency of the information to be recorded is lower than the bit frequency of the digitized signals as in the Compact Disc system of the RDAT system, for example, due to data compression techniques. This means that the bit frequency of the digital signal to be recorded no longer corresponds to the bit frequency of the signals for which the most conventional recording and reading devices for digital information have been designed. This difference in bit frequency can be compensated during the recording operation by using an input buffer memory 6, for example a memory of the First-In-First-Out type (FIFO) which is arranged between an input 5 for receiving the digital signal Va to be recorded and a control circuit 7 for controlling the read/write head 3 and which is loaded at a rate which corresponds to the bit frequency of the received digital signal Va and from which the stored information is retrieved and subsequently supplied to a data input of the control circuit 7 at a retrieval rate which is related to the scanning rate during the recording operation. If the scanning rate corresponds to the conventional scanning rate of 1.2 - 1.4 m/s, as in recording and reading CD signals, a retrieval rate which corresponds to the bit frequency of the EFM-modulated CD signal is very suitable. The read/write head 3 can be brought to a write state *via* the control circuit 7, in which state the head 3, in response to the write signal supplied by the control circuit 7, provides a corresponding information pattern in the scanned portion of the record carrier 2. The read/write head 3 can also be brought to a read state *via* the control circuit 7. In this read state the head 3 supplies a read signal VI in accordance with the information pattern in the scanned portion of the record carrier 2.

To control the loading of the input buffer memory 6, the device may comprise a clock signal generator 8 for supplying the input buffer memory 6 with the clock signal cl2 related to the bit frequency of the signal Va.

The recording device may further comprise a second clock signal generator 9. The clock signal generator 9 applies a retrieval clock signal cl3 to the input buffer memory 6, which signal is used for retrieving the information stored in the input buffer memory 6, said retrieval clock signal cl3 having a frequency which is preferably related to the scanning rate during recording. In order that a limited storage capacity for the input buffer memory 6 is sufficient, the recording can be controlled in such a way that the information stored in the input buffer memory 6 is retrieved and subsequently recorded when a given upper limit of the filling level of the input buffer memory 6 is exceeded. Retrieval and recording of information is sustained until the filling level has come below a given lower limit, whereafter the retrieval and recording process is interrupted until the filling level has exceeded the upper limit again. For such a control the system comprises recording control means which consist of, for example, a program-controlled control unit 10 of a conventional type which is loaded with a suitable program. The control unit 10 is coupled to the radial displacement system 4 for supplying a control signal so as to realize a radial scanning jump across a defined number of tracks. The control unit 10 is further coupled to the clock signal generators 8 and 9 for activating and deactivating the generation of the clock signals supplied by the generators 8 and 9. The control unit 10 also applies a control signal to the control circuit 7. The control circuit 7 is formed in such a manner that, dependent on the received control signal, the read/write head 3 is brought to the read state or to the write state. In the read state the read/write head 3 supplies a read signal VI which represents the information recorded at the scanning location in the track portion scanned by the read/write head 3. In the write state the information received at the data input of the control circuit 7 is recorded by means of the read/write head 3. The input buffer memory 6 further supplies a filling level indication signal Vg1 which is indicative of the filling level of the input buffer memory 6 for the purpose of controlling the recording operation. Finally the read/write head 3 is coupled to the control unit 10 for supplying the read signal VI so as to determine an address signal indicating the position of the scan-

ning point.

The recording control will hereinafter be elucidated with reference to Fig. 2 showing a flow chart of a suitable control program for the control unit 10, and Fig. 3 which is a plan view of the record carrier 2 with the track present on it, denoted by the reference numeral 31.

The program whose flow chart is shown in Fig. 2 comprises a step S1 which is performed if it is desired to record the information signal Va applied to the input 5. During the execution of step S1 the read/write head 3 is brought, in a conventional manner under the control of the control unit 10, to a desired radial position where the recording is to start. Subsequently a start is made with the loading of the signal Va into the input buffer memory 6 during the execution of step S2. After the execution of step S2 it is ascertained with reference to the filling level indication signal Vg1 during the execution of step S3 whether the filling level of the input buffer memory 6 has exceeded a given value Vmax. As soon as the filling level has exceeded this value, it is tested in step S4 whether the information stored in the input buffer memory 6 relates to the first packet of the information to be recorded. If positive, a search is made on the track where the recording operation can start during the execution of step S4a and in a way as described, for example, in European Patent Application EP-A-0 325 329 (PHQ 88.002) which is herein incorporated by reference. Subsequently the recording operation is started during the execution of step S5. During the execution of step S5 the generation of the retrieval clock signal cl3 is activated so that the information stored in the input buffer memory 6 is applied to the control circuit 7 in synchronism with the retrieval clock signal cl3. During the execution of step S5 the read/write head 3 is also set to the write state, with the result that the information applied to the control circuit 7 is recorded. For the purpose of illustration, the reference numeral 30 in Fig. 3 indicates the point where recording in the spiral track 31 begins.

The rate at which the information is retrieved from the input buffer memory 6 is higher than the rate at which the input buffer memory 6 is loaded so that the filling level of the input buffer memory 6 will decrease during recording. In step S6 it is tested whether the filling level of the input buffer memory comes below a given limit Vmin. If positive, the location in the track where the recording will be interrupted is determined during step S7. Moreover, information indicating this location is stored, for example, in the memory of the control unit 10. For a detailed description reference is made to the previously mentioned application EP-A-0.429.139 (PHN 13.146). During the execution of step S8 the read/write head 3 is set to the read mode at the instant when the position is reached where the recording must be interrupted, and simultaneously the retrieval of the information from the input buffer memory 6 is interrupted by deactivating the generation of the retrieval clock signal cl3. In Fig. 3 the point at which the recording in the track 31 is interrupted is denoted by the reference numeral 32. After the execution of step S8 it is determined during step S9 whether all information packets have already been recorded. If negative, step S10 is carried out in which the read/write head jumps over one or more tracks to a turn of the spiral track preceding the track portion in which the recording was interrupted. The jump is denoted by arrow 33 in Fig. 3. As a result of the radial jump the track portion located before the point 32 where the recording was interrupted is scanned. During the execution of step S11 it is tested with reference to the read signal VI whether the point 32 has been reached again, for example, on the basis of the address information present in the track. Subsequently, the recording operation is resumed by performing step S5. During recording the recording operation is temporarily interrupted at the positions in the track 31 denoted by the reference numerals 33,...,36. This process of interrupting and resuming the recording operation continues until in step S9 the last packet of information to be recorded is detected and step S12 is carried out. During the execution of step S12 the loading of the digitized information in the input buffer memory 6 is stopped by deactivating the load clock signal cl2.

The embodiment of the recording device according to the invention shown in Fig. 1 comprises an analysis circuit 11 for deriving, from the read signal VI, an indication signal Vinc which is indicative of the quality of the read signal VI. The analysis circuit 11 may comprise, for example a circuit supplying a signal as an indication signal indicating whether a given write parameter such as, for example the write power deviates from the optimum setting. If the information to be recorded has a duty cycle of 50%, an analysis circuit may be used which determines the duty cycle of the read signal. When recording a d.c.-free signal, the analysis circuit 11 may be a circuit for determining the d.c. component of the read signal. However, analysis circuits of a different type are also applicable, for example analysis circuits as described in WO 91/09399, EP-A-0.404.205 (PHN 12.994), EP-A-0.404.247 (PHN 12.984), or EP-A-0.442.566 (PHN 13.242), which Patent Applications are herein incorporated by reference. The indication signal Vinc is used for adapting the write parameter. This may be effected, for example by means of a suitable hard-wired circuit. In the embodiment shown in Fig. 1 the indication signal is applied to the control unit 10 which is loaded with a suitable setting program

setting, *via* a signal line 12, a write parameter such as, for example the write power set by the control circuit 7 in dependence upon the indication signal and in a conventional manner, as described, for example in the aforementioned Patent Applications EP-A-0.404.247 (PHN 12.984), EP-A-0.404.251 (PHN 12.994) or EP-A-0.442.566 (PHN 13.242).

Fig. 4 shows by way of example a flow chart of a suitable control program. This program may be performed, for example before the program step S5 described with reference to Fig. 2 is performed. For the purpose of illustration this program is indicated by Pinst in the flow chart of Fig. 2.

The program Pinst comprises a step S40 in which the indication signal Vinc is written. In step S41 it is determined on the basis of the written indication signal Vinc whether the write power PW which has been set is too high or too low. If the indication signal Vinc indicates that the write power which has been set is too low, step S42 is carried out in which a setting value PW is raised by an adaptation value. However, if it is apparent during the execution of step S41 that the write power which has been set is too high, the setting value is lowered by the adaptation value during the execution of step S43. During the execution of step S44 the setting value PW is applied to the control circuit 7 which sets the write power at a level fixed by the setting value PW.

Fig. 5 shows a further embodiment of the recording device according to the invention. The components of the device corresponding to components already described with reference to Fig. 1 have the same reference numerals.

The signal path between the input 5 and the control circuit 7 incorporates a signal processing unit 50 which adds error-correcting codes in a conventional manner to the information signal to be recorded. Such a signal processing circuit may be, for example of a type as is generally used for recording digital signals in accordance with a CD standard. In the embodiment described the signal processing circuit 50 is arranged between the input 5 and the input buffer memory 6. However, the circuit 50 may also be arranged in the signal path between the input buffer memory 6 and the control circuit 7. The read signal VI is applied to a read circuit 51 of a conventional type for regaining the recorded information. The output of the read circuit 51 is applied to an error detection circuit 52 of a conventional type. The error detection circuit may be adapted to detect errors on the basis of the error-correcting codes added to the information. The error detection circuit 52 is coupled to a counting circuit for counting the errors detected by the error detection circuit 52 in accordance with a given criterion. Such a criterion may be, for example the Block Error Rate as is conventionally used for testing the quality of CD signals which have been read. For a detailed description of a device for counting these errors reference is made, for example to US 4,665,513, which document is herein incorporated by reference. However, also other counting criteria different from those described in said document are usable. The counting circuit 53 indicates as indication signal Vinc the number of detected errors. The counting circuit 53 and the error detection circuit 52 jointly constitute a further embodiment of circuit 11 for the indication signal Vinc.

The number of errors indicated by the indication signal Vinc indicates the quality of the recorded information pattern. If the number of errors indicated by Vinc exceeds a number fixed by a predetermined number, it is desirable to resume the recording of this information in an additional recording cycle. In the device according to the invention in which the recording is each time interrupted to fill the input buffer memory 6, the resumed recording operation may be carried out during the period when the retrieval of information from the input buffer memory 6 is interrupted.

However, it is then required for the recorded information to be temporarily stored after the recording operation until the time interval has elapsed in which the resumed recording operation possibly is to take place.

For this purpose the embodiment shown in Fig. 5 is provided with an additional memory 54 to which the information to be recorded and retrieved from the input buffer memory 6 is applied.

The output of the input buffer memory 6 and the additional memory 54 are each connected to one of the inputs of a two-port multiplex circuit 55. The output of the multiplex circuit 55 is coupled to the input of the control circuit 7. Under the control of the control unit 10 one of the inputs of the multiplex circuit 55 may be selectively interconnected to its output. The process of loading and retrieval of information from the input buffer memory 6 and the additional memory 54 is conventionally controlled by the control unit 10. A flow chart of a program to be performed by the control unit 10 for controlling the device is shown in Fig. 6.

Step S60 is a step in which the scanning point is displaced under the control of control unit 10 towards the track portion where the end of the last recorded packet of information is located. As soon as this position is reached, step S61 is performed in which a packet of information is retrieved from the input buffer memory and applied to the control circuit 7 *via* the multiplex circuit 55. Simultaneously, the read/write head 3 is brought to the write state *via* the control circuit 7 so that an information pattern corresponding to the retrieved information is recorded in the scanned portion of the track 31.

Furthermore, the additional memory 54 is controlled during the execution of step S61 in such a way that the packet of information retrieved from the input buffer memory 6 is stored in the memory 54. After the retrieved packet has been recorded, step S62 is carried out. Under the control of the control unit 10 the scanning point is brought to the point in the track where the recording of the last recorded packet was started.

As soon as this point has been reached, the recorded information is read during the execution of step S63, while the number of erroneously read information units is detected by the error detection circuit 52. These detected errors are counted by the counting circuit 53. The signal Vinc indicating a number of errors counted in accordance with a given criterion is passed on to the control unit 10.

In step S64 it is ascertained on the basis of the signal Vinc whether the number of detected errors is so high that a resumed recording operation is desired. If positive, step S65 is performed. In this step the scanning point jumps to the point on the track 31 where the recording of the last recorded packet was started. As soon as this point is reached, step S66 is carried out. In this step the last packet stored in the memory 54 is retrieved under the control of the control unit 10 and applied to the control circuit 7 *via* the multiplex circuit 55. Simultaneously, the read/write head 3 is brought to the write state *via* the control circuit 7.

As soon as the resumed recording operation is finished, the program is continued with step S67. In this step a waiting time is observed until sufficient information is present in the input buffer memory 6 to record a subsequent packet of information. Subsequently step S60 is carried out again. If it has appeared during the execution of step S64 that resumed recording is not necessary, step S64 is not followed by step S65, but step S67 is performed directly.

The criterion used in the above-mentioned embodiment for determining whether a resumed recording operation is desirable may imply, for example that the number of errors per information block should not exceed a predetermined value. As a result of the added error- correcting codes the majority of the detected errors may generally be corrected. Such errors are not fatal, in contrast to errors which are no longer corrigible. It is therefore preferred to have the decision whether a resumed recording operation is to take place depend on the number of detected incorrigible errors. The detection of such incorrigible errors may be realized in a similar manner as is common practice in reading Compact Discs.

The invention has been described hereinbefore with reference to a recording system for rotating disc-shaped record carriers. However, it should be noted that the use of the invention is not limited to recording and reading systems of rotating disc-shaped record carriers. In principle, the invention may be used in any recording and reading system in which it is possible to scan a previously located portion of the track. The use of the invention is neither limited to optical recording and reading systems but may also be used in magnetic recording and reading systems.

It is further to be noted that the decision criteria based on which the recording and/or reading operation is interrupted and resumed are not limited to the decision criteria described. For example, the decision criteria as described in WO 91/11002 are also usable. It is further possible, for example, to interrupt the recording and/or reading operation each time after reading or recording information from/in an integral number of turns of the spiral track. It is also possible, for example to resume the recording and/or reading operation when a minimum time interval has elapsed. It is always essential that the storage capacity is chosen to be sufficiently large to compensate for occurring fluctuations in the quantity of stored information and that the available time between two recording cycli of the recording operation is sufficient to scan the last recorded information packet at least partly for the purpose of determining the indication signal Vinc. In the embodiment shown in Fig. 5 it is important that the available time between two recording cycli is sufficient to read both the last recorded packet and to possibly re-record this packet.

Claims

1. A device for recording information on a record carrier, which device comprises a read/write head of a type which can be brought to a read and a write state and is adapted to provide, in the write state in response to a write signal, a corresponding information pattern in a portion of the record carrier which is scanned by a scanning point fixed by the position of the read/write head, and which is adapted to provide, in the read state, a read signal which is indicative of the information pattern in the portion of the record carrier scanned by the scanning point, a driving device for causing the scanning point to scan the record carrier in accordance with a track-shaped path, an input buffer memory for storing information to be recorded at a given load rate, a retrieval circuit for retrieving a packet of information from the input buffer memory at a retrieval rate which is higher than the load rate, a write circuit for converting the packet of retrieved information into write signals for the read/write head, control means for interrupting the recording opera-

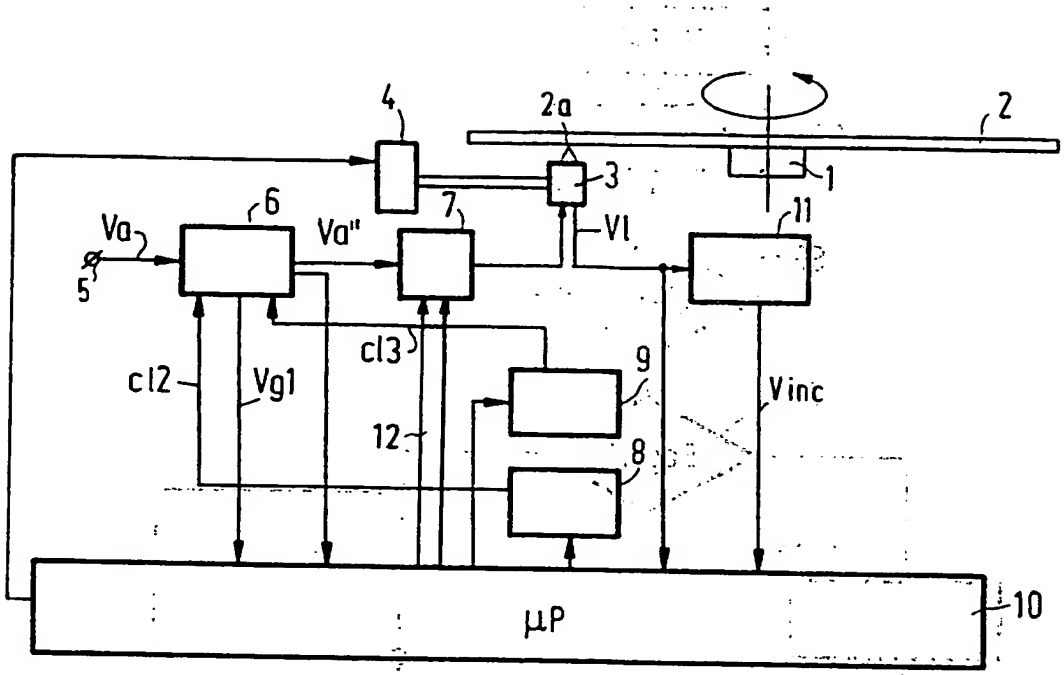
tion after the information pattern corresponding to said packet has been recorded, for a repeated scanning of the information pattern corresponding to the last retrieved packet and for retrieving a subsequent packet of information from the input buffer memory and starting the recording of an information pattern corresponding to said subsequent packet in a portion of the record carrier adjoining the last recorded information pattern, such that a filling level of the input buffer memory remains between given limits, characterized in that the device comprises means for deriving an indication signal which is indicative of the quality of the recorded information pattern on the basis of the read signal which is supplied by the read/write head during the repeated scanning operation.

2. A recording device as claimed in Claim 1, characterized in that it comprises means for adapting, in dependence upon the indication signal, the write parameter which influences a relation between the information to be recorded and the information pattern provided and corresponding to said information.

3. A recording device as claimed in Claim 1, characterized in that the device comprises a read circuit for regaining the recorded information from the read signal, in which the means for supplying the indication signal are provided with error detection means for detecting errors in the regained information and with means for counting errors in the read information in accordance with a given counting criterion, the means for deriving the indication signal being adapted to supply an indication signal which is indicative of the number of counted errors.

4. A recording device as claimed in Claim 3, characterized in that the device comprises means for detecting whether the indication signal satisfies a predetermined criterion, storage means for storing the information associated with the last recorded information pattern, the control means being adapted to repeat the recording of at least those portions of the information stored in the storage means for which the indication signal does not satisfy said criterion.

5. A recording device as claimed in Claim 4, characterized in that the device comprises means for adding error-correcting codes to the information to be recorded, the means for detecting errors being adapted to detect errors which are not corrigible by means of the error-correcting codes, the indication signal indicating the number of incorrigible errors.


4
2a
2
3
1
6
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Va"
Vl
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c13
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c12
Vg1
Vinc
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µP
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FIG.1

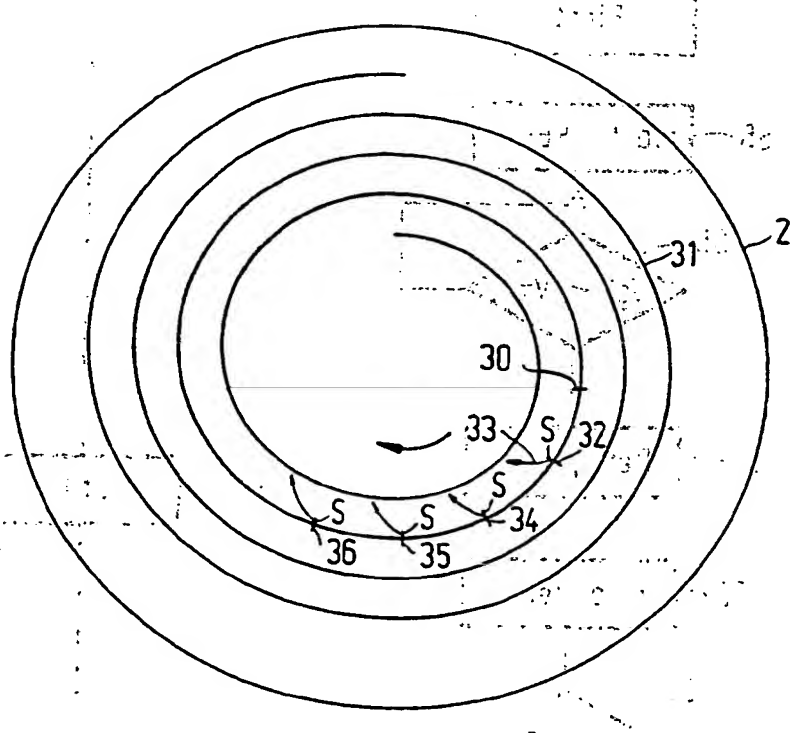
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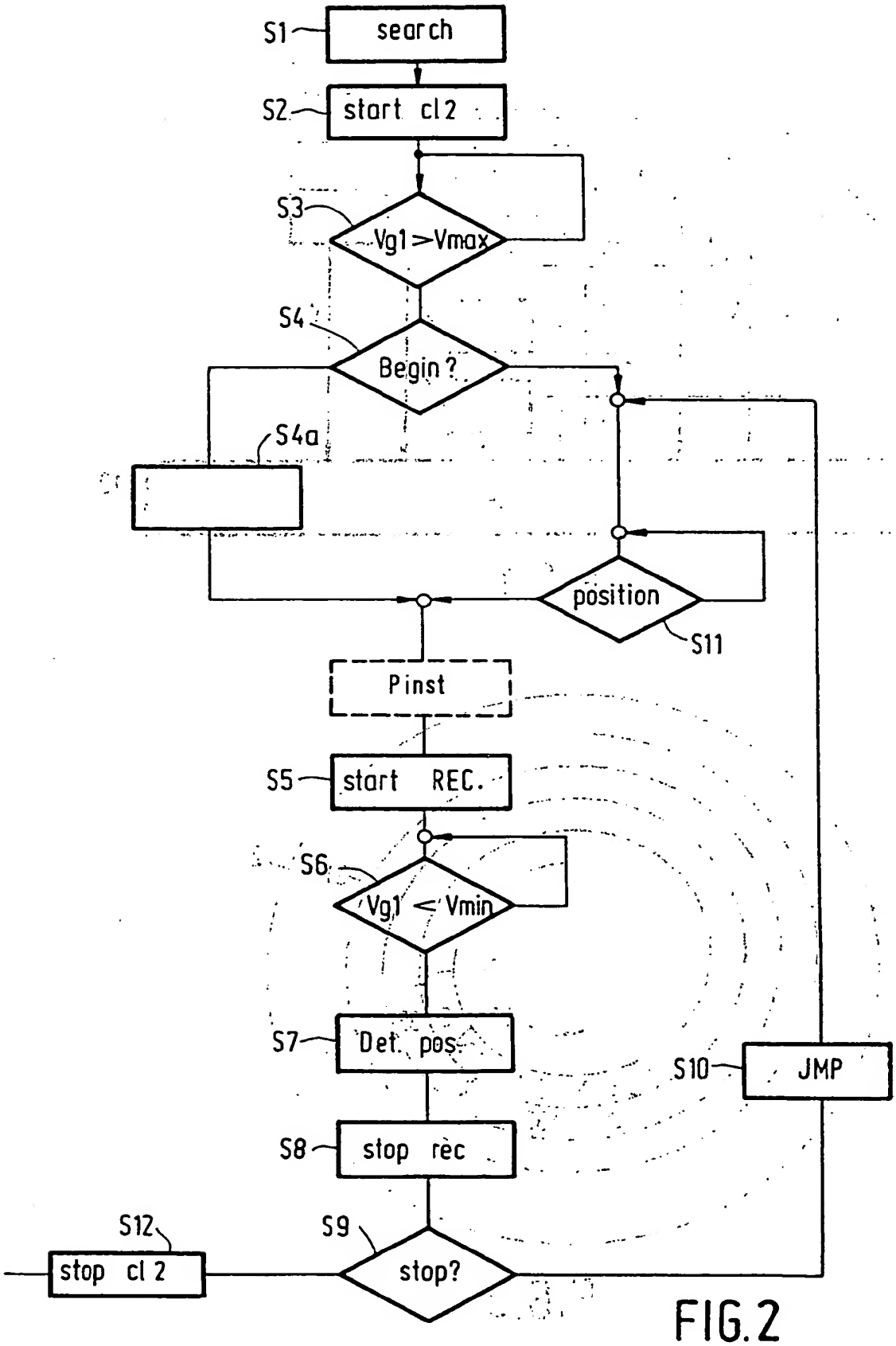
FIG.3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S2
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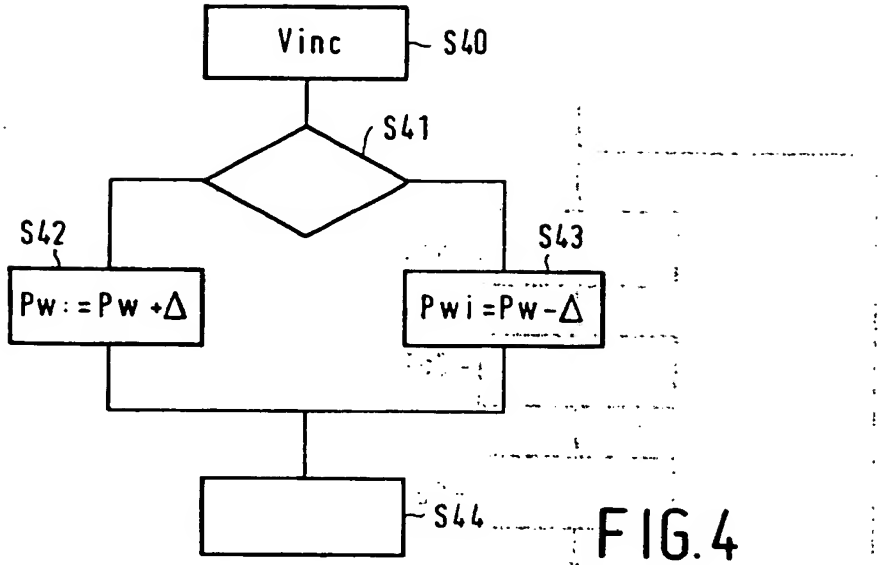
S3
Vg1>Vmax
S4
Begin?
S4a
position
S11
Pinst
S5
start REC.
S6
Vg1 < Vmin
S7
Det. pos
S10
JMP
S8
stop rec
S12
S9
stop cl 2
stop?

FIG.2


Vinc
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S41
S42
S43
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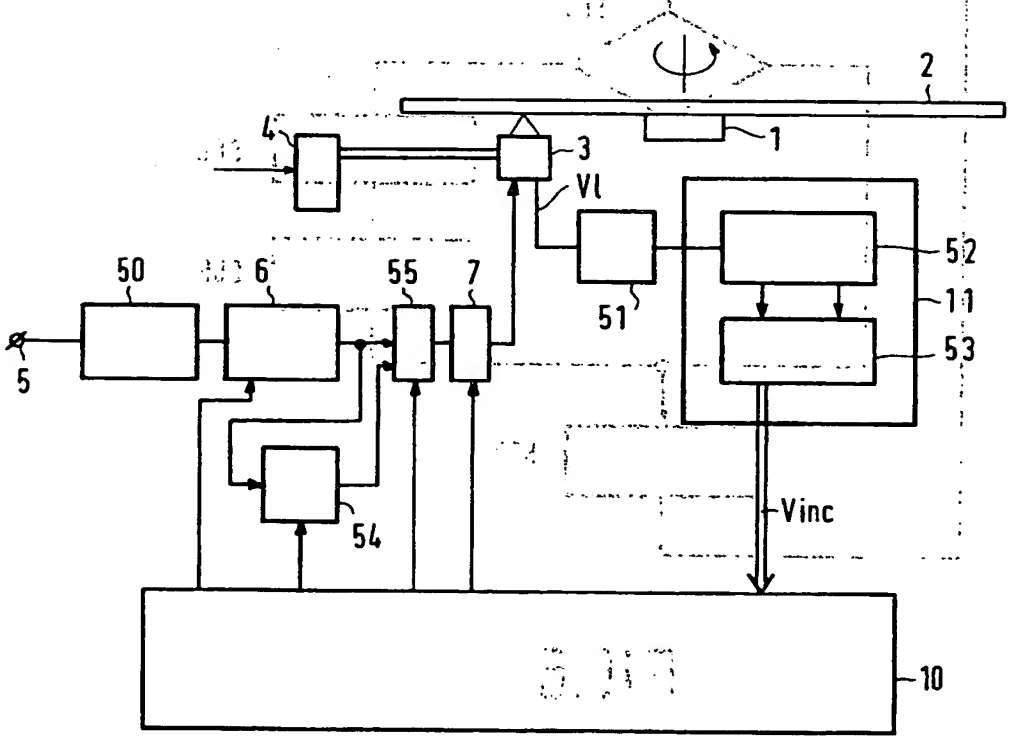
Pwi=Pw-Δ
S44

FIG.4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Vinc
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FIG.5

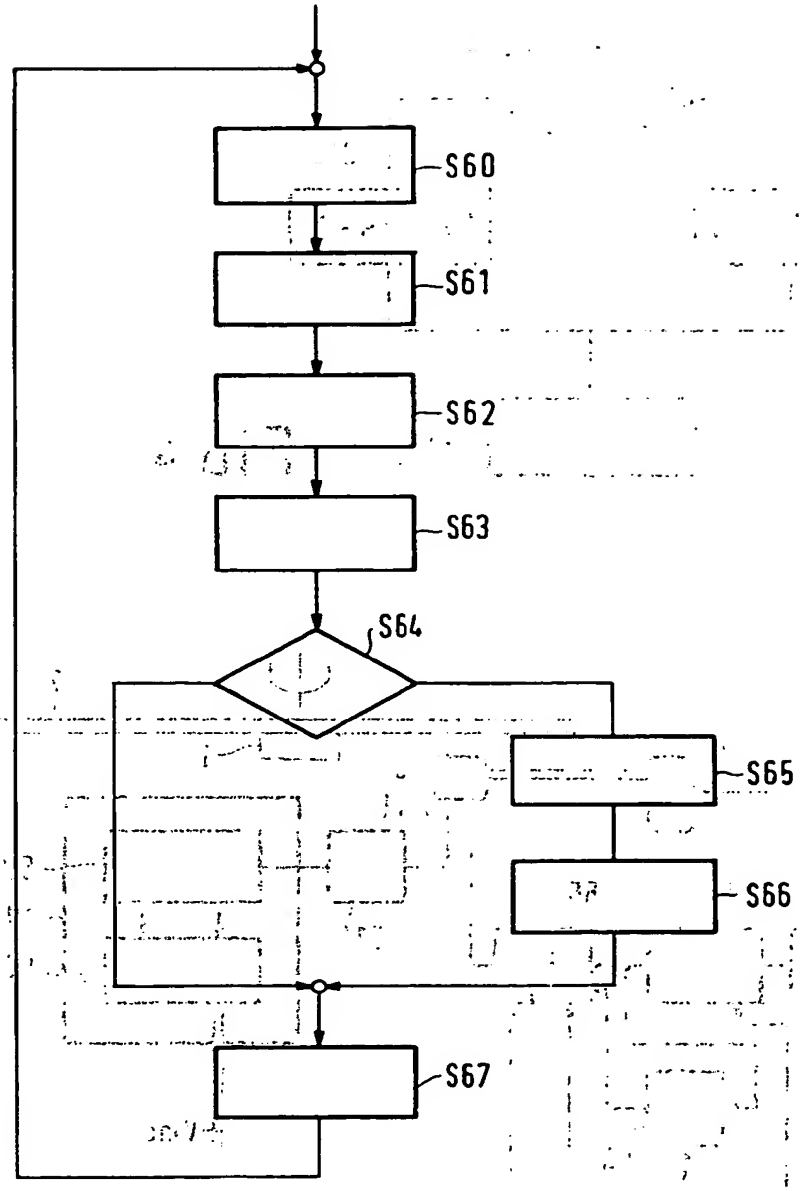

FIG.6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 20 0547

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 465 053 (SONY CORPORATION) * column 10, line 30 - column 11, line 36 * ---	1	G11B20/10 G11B27/34 G11B20/18
A	EP-A-0 464 216 (SONY CORPORATION) * column 10, line 40 - column 11, line 32 * ---	1	
D,A	EP-A-0 429 139 (N.V.PHILIPS GLOEILAMPENFABRIEKEN) * column 6, line 13 - column 10, line 21 * ---	1	
D,A	EP-A-0 463 183 (SONY CORPORATION) * column 11, line 15 - column 13, line 19 * ---	1	
D,A	US-A-4 665 513 (R.WENGLER) * column 2, line 43 - column 6, line 26 * ---	1,3	
A	ELEKTOR ELECTRONICS vol. 15, no. 171, October 1989, CANTERBURY GB pages 12 - 15 T.GIFFARD 'CD ERROR DETECTOR' * the whole document * ---	1,3,5	TECHNICAL FIELDS SEARCHED (Int. Cl.5) G11B
P,A	EP-A-0 491 563 (PIONEER) * column 4, line 5 - line 41 * ---	1	
A	EP-A-0 426 353 (INTERNATIONAL BUSINESS MACHINES CORPORATION) * page 4, line 51 - page 5, line 31 * ---	1	
A	EP-A-0 073 519 (SONY) * page 5, line 22 - page 6, line 4 * -----	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 JUNE 1993	KELPERIS K.

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